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THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXVI, No. 7 SEPTEMBER, 1932 WHOLE No. 216

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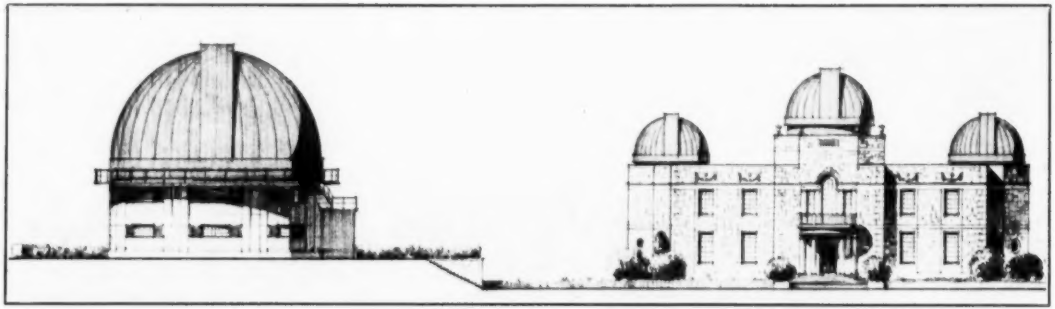
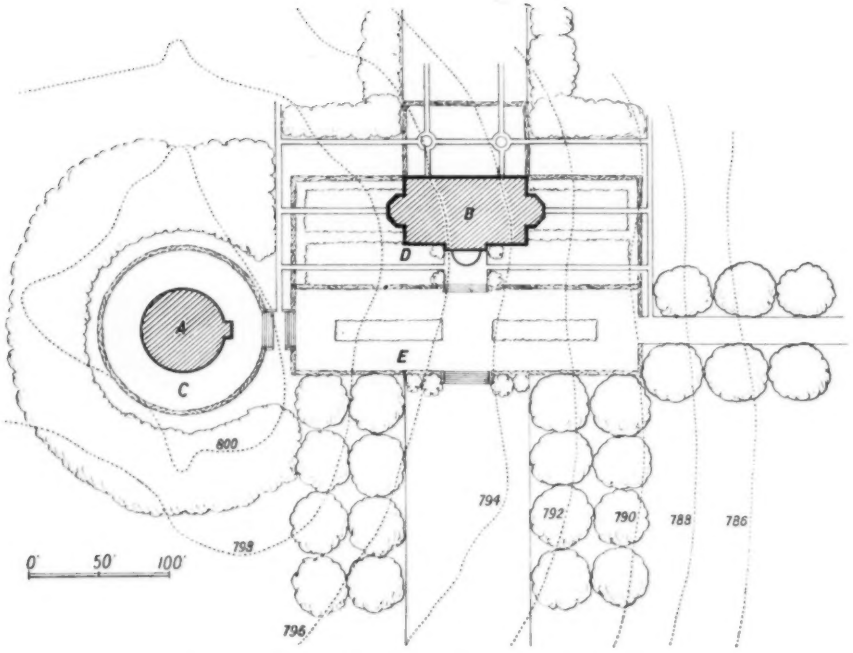
PLATE IV



THE DAVID DUNLAP OBSERVATORY

The above picture, from a drawing supplied by the architects, shows the western elevation of the David Dunlap Observatory, construction of which will begin immediately. The dome at the left is 61 feet in diameter and will cover the 74-inch reflector. The Administration Building at the right will be 91 feet long by 49 feet wide, with semi-octagonal projection at the ends. The building will be erected with Credit Valley limestone. In one of the smaller domes will be mounted a 19-inch reflector, in the other a battery of photographic telescopes, and in the centre dome will be a 10-inch refractor.

PLATE V.



GROUND PLAN OF THE DAVID DUNLAP OBSERVATORY

A is the 61-foot building for the great reflector, on a platform *C*, which is 800 feet above sea-level. On the area *D*, 795 feet in elevation, is the Administration Building *B*. The area *E* has an elevation of 792 feet. The dotted contour lines show the present elevations. The hill falls away in all directions, the summit being about 75 feet above the surrounding country.

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THE DAVID DUNLAP OBSERVATORY

By C. A. CHANT

(With Plates IV and V)

IN Plate IV is shown the western elevation of the two chief buildings of the David Dunlap Observatory, the erection of which will commence immediately. As already stated in this JOURNAL, it is being provided as a memorial to the late David A. Dunlap by his widow, Mrs. Jessie D. Dunlap, with whom is associated their son, Mr. Moffat Dunlap. When completed it will be presented to the University of Toronto, and will be conducted by the Department of Astronomy.

The circular building at the left, surmounted by a dome, is 61 feet in diameter. The framework is of steel with hollow walls two feet thick, sheathed inside and outside with galvanized iron. The inner and outer surfaces of the dome will be covered with a special kind of papiermache, with sheet copper on the outside. This building will house the 74-inch reflecting telescope which was ordered in May, 1930, from Sir Howard Grubb, Parsons and Co., of Newcastle-on-Tyne, England. The mounting is almost completed, but the date when the large mirror will be ready is uncertain. Every effort is being made to prevent undue delay. The dome is being supplied by the same firm and is almost completed.

The Administration Building is shown at the right. The plans

for it have been prepared by Mathers and Haldenby, Architects, Toronto, and the contract for its erection has been awarded to Sullivan and Fried, a Toronto company. It will contain offices, library, lecture room, reception room, laboratories, computing rooms and workshop. It will be 91 feet long by 49 feet wide, with a semi-octagonal projection on each end. The two end domes are 21 feet, the centre one 25 feet, in diameter. In one of the smaller domes will be mounted the 19-inch reflecting telescope constructed at the University by Prof. R. K. Young, while in the other will be three astronomical cameras on a single mounting. The chief parts of these cameras are already on hand and the mounting will be made in the observatory workshop. In the central dome it is intended to place a 10-inch refractor, which will be used for the observation of planets, comets, occultations, and double stars, and will also be available for public purposes.

The Administration Building will be constructed of Credit Valley limestone with trimmings of Queenston stone, while the square entrance hall and stairway will be finished in travertine.

In Plate V is shown the ground plan of the buildings. They will be located in the midst of a 177-acre plot of land near the village of Richmond Hill, about twelve miles north of Toronto. This large acreage, now farmland, is to be made into a park to be known as the David Dunlap Park. It will be developed in a scientific way by the Faculty of Forestry. The dotted contour lines show the elevation above sea-level. The great dome will be on a platform 800 feet above the sea, on an area five feet lower the Administration Building will be placed, and in front of the latter will be an area three feet lower still. These areas will be bordered with hedges, and decorated with shrubs and flowers.

THE EARTHQUAKES OF OCTOBER, 1931, IN THE SOLOMON ISLANDS

By S. Gold

AMONG the oldest seismic regions of the earth are the Solomon Islands. These islands lie in the Southern Pacific about 1000 miles northeast of Australia. They are volcanic and mountainous.

During the month of October, 1931, a series of earthquakes rocked the eastern portion of these islands. Two of the shocks, occurring on the 3rd and 10th respectively, were extremely severe. A very large tidal wave followed the earthquake on the 3rd and swept everything before it. The parts affected by the wave are indicated on the map.

As a result of these earthquakes about 50 persons were killed and 700 rendered homeless. It is difficult to estimate the total loss of life because, in some parts, the natives are wild and uncivilized.

There are several reasons for the casualties not reaching great proportions. The natives live in simple bamboo and leaf-thatched houses and there are no heavily constructed buildings. Also the population is more or less scattered. Further, along the coast of San Cristoval, which was mostly affected, there are a large number of land-locked harbours formed from old craters, the broken lips of which form the entrances.

Preliminary locations by the United States Coast and Geodetic Survey place the epicentre of the first shock at 14°S., 160°E. It would seem then that tremendous damage must have occurred on the islands Rennell and Bellona, from which there has been no communication as yet.

For the second earthquake the coordinates were computed to be 8°S., 160°E. This agrees with the observed data as this earthquake was felt quite severely on Malaita, Florida, Ysabel and Guadalcanal.

At Ottawa the following determinations were made from the seismograms:

	Time at Origin	Δ	Maximum earth displ'nt
October 3	19-13-21 G.M.T.	13,700 km.	224 microns
October 10	0-19-47 G.M.T.	13,300 km.	161 microns

At the Riverview College Observatory, Sydney, Australia, 20 distinct shocks, all probably originating around the Solomon Islands, were registered during the month of October.

FIG. 1. Map showing the location of the earthquakes.

The main damage on each island is noted in what follows.

San Cristoval. The first quake shook this island so violently that two villages disappeared. Then a huge tidal wave between

30 and 40 feet high, swept away 18 villages on the southern coast. Water and sewage services were destroyed at the government residence at Kirakira.

Many parts of the coast line were entirely altered. Salt water sweeping over the island destroyed vegetation and washed surface soil away, showing rocks and coral reef.

Ugi. Violently shaken by the earthquakes.

Malaita. Heavy damage occurred. At Su-u the tidal wave ruined the cement breakwater and the reinforced cement steamer wharf. At Takataka great damage to buildings and goods was reported.

Between Auki and Su-u, off the western coast of Malaita, there is an extensive barrier coral reef, called the Bina Lagoon. There were several well-populated islands along the extent of this reef. The earthquakes destroyed the foundations of these islands, leaving the people swimming in the water. Heavy landslides occurred on the mainland directly opposite.

At Oni Pusu Harbour the reef rose several feet.

Florida. Considerable destruction of property reported. The reinforced concrete wharf at Makambu sank about 12 inches and cracked in several places. Carpenter's wharf at Tulagi was shaken down.

On October 13, 1931, due to a sharp sudden jolt, the harbour bed at Carpenter's wharf rose from 10 to 20 feet, preventing the berthing of ships.

Guadalcanal. Numerous huge landslides occurred among the mountains. Due to the tidal wave a small village on the eastern end, near Aola, disappeared. No other serious damage was reported.

Ysabel. At Fulakora the tremors were quite strong, but only minor damage resulted.

Rennell and Bellona. No news has been received yet from here as these islands are visited only by the Government vessel once or twice a year.

These two earthquakes were also felt by people on ships which happened to be in the vicinity of the islands.

On October 3, the labour recruiting schooner *Mendana* was about one mile off the coast of San Cristoval when the jolts started. A

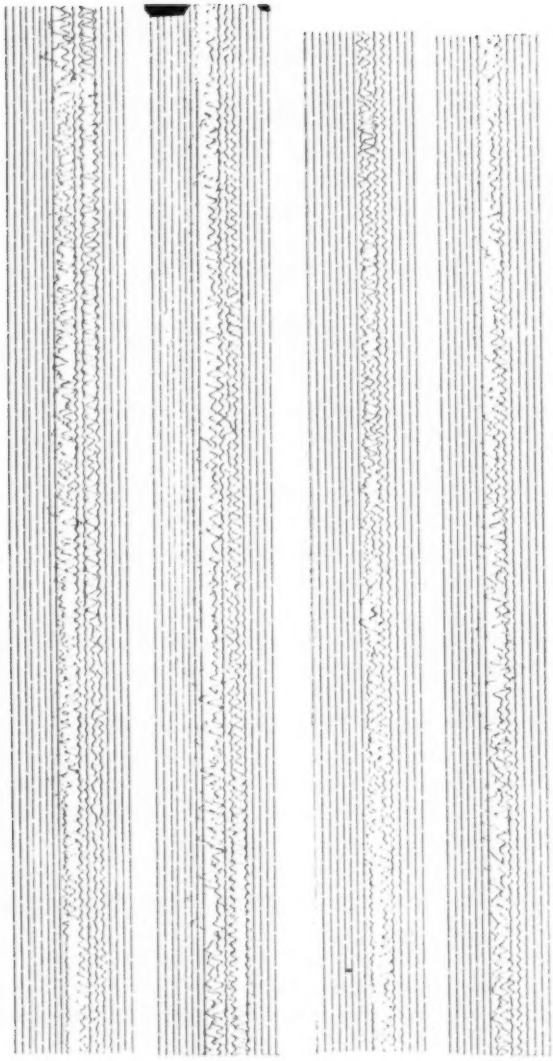

FIG. 2. The two large Solomon Islands earthquakes of October, 1931, as recorded at Ottawa on Milne-Shaw seismograph No. 17, EW component. The upper two strips show the record of October 3 to 5, 1931; the lower two strips that of October 8 to 10, 1931.

submarine disturbance developed around the ship which caused it to roll about alarmingly. The captain reported that the ship's bottom was struck by boulders and sand and there was a smell of sulphur.

On October 10, the steamer *Montoro* was about 60 miles from Tulagi (Florida) when the earthquake occurred. The ship rolled so violently that it was thought she had struck the reef.

One of the Jesuit Fathers of Visale (Guadalcanal) was in his boat about 25 miles west of Guadalcanal on October 10. He reported that the boat seemed to be hit by sledge hammers on the bottom. The rudder of the boat was damaged.

Most of the information necessary for this article was supplied by Dr. J. Svensen of Ovi Harbour, Guadalcanal, in the form of letters and newspaper clippings. Due acknowledgement is hereby made.

Dominion Observatory,
Ottawa,
April, 1932.

THE DEPTHS OF SPACE*

By C. A. CHANT

IN early times the universe was believed to be of but small extent. The heavens were just overhead and the gods often came down to mingle with mortal men. Their exploits are frequently referred to in the ancient classics. As knowledge grew, the sky receded, and it has continued to do so until now there is nothing which humbles a person more than to meditate on the distances of the celestial orbs.

It is my aim this evening to indicate briefly how the astronomer has continually extended his explorations farther and ever farther into the depths of space.

At the outset it is desirable that you, my indulgent friends, should have some conception of our position in the universe. The sun is a star, giving out light and heat of itself, and the earth is one of a number of much smaller bodies, called planets, revolving about it. The sizes of their orbits when expressed in miles seem very large, but when we find out the distances to the millions of other suns, which appear as bright dots on the sky, we realize that our solar system occupies but a pin-head of space, while the rest of the universe is inconceivably remote. The distances from star to star, however, are not infinite, although they are extremely great, as we shall see.

A few years ago a well-equipped party attempted to climb Mt. Everest, the world's highest mountain. They did not get within 2,000 feet of the top, and yet we know with accuracy that the the summit is 29,140 feet above the sea. How was it measured? The principle of the method is quite simple. The surveyor chooses a station some miles away and measures the altitude of the summit, that is, he measures the angle which a line directed towards the summit makes with the horizontal plane. Then he moves towards the mountain an accurately-measured distance, say half a mile, and

*Broadcast over CKGW, Toronto, February 5, 1932, by request of the National Council of Education.

again determines the altitude of the summit. From the two angles and the half-mile base the height is readily calculated.

This method has been applied to the moon, the two stations being far-separated observatories, such as Berlin and the Cape of Good Hope. The distance of the moon from the earth, thus measured, is approximately 240,000 miles. The same method has been applied to the sun, but with great difficulty as its distance is very large compared to any base-line on the earth. The sun's distance is about 93,000,000 miles, which is nearly 400 times that of the moon. Knowing the earth's distance from the sun, the distances of the other planets are easily deduced. Thus has the astronomer carried his surveying operations to the limit of the solar system.

But how about the stars—those other suns, which perhaps have planetary systems of their own? All base lines on the earth are hopelessly small for measuring their immense distances. But there is another base-line available, namely, the diameter of the earth's orbit, which is 186,000,000 miles in length. A simple illustration may assist you to understand how it is used.

Suppose that through a window three feet in width you observe a telephone pole on the other side of the road. Looking at it from the right edge of the window, the pole appears to be just at the left side of a bright cloud, which we shall assume does not change during our experiment. Moving to the left edge of the window, you look at the pole again. It now appears just at the right side of the cloud; that is, when you move your eye three feet to the left, the pole appears to be displaced to the right the width of the cloud. If now you can measure the angular width of the cloud, that is, can determine the angle between the lines drawn from your eye to the two sides of the cloud, then the distance of the pole from you can be calculated. I am sorry I cannot demonstrate this to you, but to do so I should require to have you before me and a blackboard and chalk at my disposal.

Let us now apply this method to our problem. The astronomer to-night points his telescope towards a star, which we shall suppose to be a comparatively near one, and observes the exact position of the star on the background of the sky. I cannot undertake to explain

just how he does this, but it can be done with great accuracy. Then the earth moves on in its orbit and in six months is 186,000,000 miles from its present location. The astronomer with his telescope again observes the star's position on the sky, and finds it is displaced slightly from its previous position. He measures the little displacement and then computes the distance of the star. This looks easy, but as a matter of fact the angle of displacement is so small that until comparatively recent times no instrument was able to measure it. The first measurements were made in 1838 and 1840.

And how far off do you think the nearest star is? It is 270,000 times as far as the distance of the earth from the sun, or 25 million million miles. This number is so large that we get lost in the figures, and it is usual to express the distance in another way. The speed of light is 186,000 miles per second or 11,000,000 miles per minute; and while light requires only 8 1/3 minutes to come from the sun to the earth, it takes over four years to come from the nearest of the stars. That star is in the Centaur, a constellation in the southern sky. If it should become extinct to-night its absence would not be observed until four years from now.

Photography has been of great service to the astronomer in making these minute measurements, and at present the distances of about 2,000 stars have been determined by the method described. These distances extend to about 300 light years.

But the astronomer well knows that the great majority of the stars are immensely farther off than this. How can he reach them?

Several methods have been devised to extend the range of exploration, but I shall refer to only two.

The first utilizes what are known as variable stars. Nearly all the stars preserve the same constant brightness from year to year, but a few have been observed to vary. One type of these variable stars is known as the Cepheids, so called because the outstanding example of the class is found in the constellation Cepheus, which is located near the pole star. The brightness of these Cepheids rises and falls with the regularity of the flashes of a lighthouse, though not so rapidly. Their periods run from one hundred minutes to several days. Now a definite relation has been found between the

luminosity, or candle-power, of a star and its period; the longer it takes to go through its changes, the more luminous is the star. If you can determine the period of one of these Cepheid variables you can deduce its absolute luminosity and also its distance.

Among the most remarkable objects in the sky revealed by photography are the globular star clusters and the spiral nebulae. The former appear like vast globes filled with stars. There are about a hundred of these clusters and the best known one in the northern sky is in the constellation Hercules. It can just be seen with the unaided eye, but in a large telescope it is a mass of sparkling jewels. The spiral nebulae are so faint that you can hardly see them with our best telescopes, but a long-exposure photograph reveals a symmetry and beauty most wonderful to behold. Now in both the clusters and the nebulae these Cepheid variables are found, and thus we are able to deduce their distances.

The distances of the clusters range all the way from 20,000 to 220,000 light years; and the question arises whether we should claim these great aggregations of suns as belonging to that section of the universe which we call our own.

The nebulae are even more distant. The nearest is 900,000 light years away, and its form suggests that it is a separate stellar system, like our Milky Way—an "island universe"—quite distinct from ours.

The second method for determining these tremendous distances is an application of the spectroscope. As many of you know, when the light from a star is analyzed by this instrument, attached to the telescope, it is actually possible to determine the speed at which the star is receding from us or approaching us. The speeds ordinarily run from 10 to 50 miles per second, occasionally reaching 100 or more. But when the spectroscope is applied to the spiral nebulae they appear to be all moving away from us and at terrific speeds—1,000, 5,000, actually as great as 15,000 miles per second—and the faster they move the smaller they appear and undoubtedly the farther they are away. Indeed the distance can be determined from the speed. The one recently discovered with a velocity of 15,000 miles per second is assigned the distance 135,000,000 light years. Further,

they are seen in almost all directions, and, as stated, they are all moving outwards from us, and thus the whole universe seems to be expanding.

These results are giving the astronomer great concern, and Einstein's theory of relativity, the fifth dimension, curved space, and other bewildering hypotheses have been invoked to explain the puzzle, but the solution is not yet in sight.

THE SUN AS A STAR*

By C. A. CHANT

ASTRONOMY is the oldest of the sciences. After thousands of years of careful observation and discussion we have reached conclusions which are now universally accepted, namely, that the sun is an immense body and around it revolve a number of smaller bodies called planets, of which the earth is one: also, that beyond the sun and the planets, at distances so great as to make our system appear as a drop in the ocean of space, are millions of other suns, which are the fixed stars,—seen as points of light on the sky.

Our sun is of superlative importance for two reasons, (1) because it is the central body and ruler of our system; and (2) because it is one of the stars, being the only one which is near enough for detailed study; and what we learn about it will help us to solve the problem of the universe around us.

One of the first things we should wish to know about the sun is, how far it is away. Now a surveyor, by measuring a base line and two angles, can calculate the distance of an object on the other side of a river; and in a similar way the astronomer determines the distance of the sun from the earth. It is approximately 93 millions of miles—a great distance indeed. An express train travelling a mile a minute without a stop would require 175 years to cover it.

Knowing the distance of the sun it is easy to deduce its actual size from the space it covers in the sky. The diameter is 864,000

*Broadcast from Station CFRB on January 18, 1932 in the University of Toronto series of broadcasts.

miles, which is 109 times that of the earth, and consequently the volume of the sun is 1,300,000 times that of the earth.

There is good reason to believe that at one time the earth and the other planets formed a part of the sun; but it was only a small part as the sun contains enough material for 332,000 earths or 750 sets of planets like those of our system. Perhaps the following illustration will make some of these distances and dimensions clearer. If we represent the sun by a ball one foot in diameter, then the earth will be a small pea at a distance of 107 feet, while the nearest of the fixed stars will be a ball 12½ inches in diameter and 5500 miles away—in Cairo or in Tokio!

It is recognized by everyone that the illumination from the sun is incomparably greater than that from artificial sources. With a bright sun, or even when it is behind a cloud, the illumination of our streets and houses would not be appreciably increased by switching on all the public and private lighting systems. There is nothing like sunlight. It is customary to state the illuminating power of a source of light, such as an electric lamp, as equal to a certain number of candles. You may be surprised to learn that if the sun were replaced by candles—at the same distance, of course—the number would be 1.575×10^{27} or 1575 millions of millions of millions, which is entirely beyond our comprehension.

Next, let us consider briefly the heat received from the sun. This is a very important matter and the Astrophysical Observatory at Washington has established stations in different parts of the earth in order to secure a continuous record of the sun's radiation. The rate at which it comes to the earth is usually expressed in calories but as at present "calories" are *out* and "vitamins" are *in* I shall use more familiar terms. Let the sunlight fall perpendicularly upon a sheet of ice one inch thick; then if none of it was absorbed by the earth's atmosphere the ice would be melted in 1¾ hours. As a matter of fact about 40 per cent of the sun's radiation coming to the earth is absorbed in the atmosphere. The heat energy which falls upon the deck of a steamer in tropical waters, if it could be used without loss, would drive the ship at a speed of about 10 knots. But the entire earth receives only the tiniest fraction of the sun's radiation, and we see that the sum total energy sent out is stupendous. Further, this enormous outflow has been

going on for millions of years. What maintains it? Not combustion. A lump of pure coal of the mass of the sun if burned in oxygen would keep up the supply for only about a thousand years. Physicists have been almost driven to the belief that this energy which is distributed with such profusion actually comes from the atoms of matter themselves—that atoms are annihilated and energy is produced. According to the theory of relativity the sun's mass is diminishing at the rate of 1.7×10^{14} or 17,000 millions of millions of tons per year, but the radiation could continue at this rate for 1.5×10^{13} or 15 millions of millions of years, so we need have no fear on that score.

Perhaps you would like to know the temperature of the sun. Indeed it may seem strange that we can find the temperature of a body 93 million miles away. But an instrument known as a pyrometer has been devised which will indicate the temperature of a furnace simply if held in front of it, and a suitable instrument directed towards the sun will give its temperature. Indeed there are several methods of arriving at its temperature. It turns out to be about 6000°C. or 11,000°F., which is sufficient to vaporize tungsten, the most refractory of the chemical elements. It must be noted, however, that this is the sun's surface temperature: at the sun's centre the temperature is probably above 10,000,000 degrees.

In our investigations we wish sometimes to use the very lowest temperatures, sometimes the very highest, You all know how a lens will converge the sun's rays to a point and produce a temperature high enough to scorch paper or ignite gunpowder. At the present time there is being constructed at the Mount Wilson Observatory in California an instrument containing 19 lenses, each 24 inches in diameter and other smaller lenses and mirrors which will concentrate sunlight upon substances within a vacuum chamber where it is hoped to obtain a temperature approaching that of the sun. The substances will be vaporized and then studied with the spectroscope.

Ever since the invention of the telescope some 300 years ago it has been used to study the surface of the sun. Soon there were discovered strange dark blotches which moved across the sun's face, from the east to the west edge. This motion was due to the

sun's rotation which was thus found to have a period of about 25 days. Continued study has shown that for weeks at a time there may be no spots. Then they increase in size and numbers and in two or three years the surface is never free from them. A few years later they will all be gone again. Actually the spots occur in cycles, the time from one maximum of spots to the next being on the average 11.1 years, though the period may be two or three years shorter or longer. The last maximum occurred in May, 1928, and we are now well on to a minimum.

Now a cycle of similar length has been discovered in the thicknes of he growth-rings of trees, and the latter we naturally associate with the quantity of precipitation; but direct attempts to show a relation between sun spots and rainfall have not been very successful. The relation seems to hold for some places, but not at others. But it should be remarked that the increase of precipitation claimed at the time of a sun spot maximum is very slight, not enough to change a dry season into a wet one. Our knowledge of the sun's radiation and of sun spots is not sufficient to enable us to predict a rainy or a dry season for any part of the country.

There are some terrestrial phenomena, however, whose relation to sun spots is undisputed. When we have many sun spots there are numerous auroral displays, or Northern lights; also, there are many disturbances of the magnetic needle.

Another interesting study has been made during the last few years, namely, the relation of sun spots to radio reception. Sufficient time has not elapsed for arriving at absolutely certain conclusions, but observations seem to show pretty clearly that the fewer the sun spots, the better the reception. If such is the case, reception will improve for several years, then it will grow poorer until about 1940, after which it will inprove again.

There are many other things which I have not time even to mention. I confidently believe that in the years to come the relations between solar and terrestrial phenomena will be determined with such certainty that the astronomer will be able to assist materially the workers on the land and in other fields as well.

THE AURORA—ARCTIC WILL O' THE WISP

By Kathleen Rice

RECALLING the many fine displays of the Northern Lights that I have witnessed in the last twenty years, it seems to me remarkable that the origin of this phenomenon is still a matter of considerable doubt, at least to the average inhabitant like myself. The inhabitant is chiefly to blame for this. His habit of life in the bush is not nocturnal; but at the same time the idiosyncrasies of the Aurora itself present special difficulties to the discovery of the laws which govern it. The hours of the occurrences, from early evening on all through the night, till the sunrise appears in the east; the ever-changing position of the lights above the earth, sometimes apparently so low overhead that one's scalp seems to tingle at their touch, on up through every stratum of the atmosphere into the highest airs; their fantastic colours and motions; all these combine to produce effects as infinite in variety as fancy itself,—and correspondingly difficult to reduce to a set of law-abiding facts.

With other happenings in nature there has been associated a certain amount of folklore, embodying the facts of common knowledge about them. These popular sayings grow out of experiences and observations through succeeding generations and are more or less revealing. For example, out of men's experiences in sailing the seas came the saying,

> Mares' tails and mackerel scales
> Lofty ships carry low sails;

or again,

> Rainbow in the morning,
> Sailors' warning;
> Rainbow at night,
> Sailors' delight.

These rhymes are accurate enough to be extremely useful rules to observe, if your work or your way is open to the weather. Certainly one fares the worse when one makes a habit of contrarying them. But I have never heard of any rule of human conduct being con-

nected, whether in the primitive or the scientific mind, with the vagaries of the Aurora. We behold and we admire and then, considerably awe-struck, we return to the warmth of our beds. It would be most interesting to learn of any folklore that might reveal the universal human reaction to this eerie sight.

Meanwhile I make bold to submit some of my own conclusions. First, then, low temperature being our chiefest worry in this extreme climate, let us consider the possibility of the Aurora affecting, or being affected by, the cold of the high latitudes. In this connection, although I have frequently observed that the more striking displays of the Northern Lights are succeeded by milder weather, I am not completely satisfied that the Aurora and the chinook form anything more noteworthy than a coincidence. Still there is an inherent likelihood in this relation between the Northern Lights and the chinook that is intriguing to mull over in one's mind. For, granted that the Aurora is an electrical effect, those manifestations of it that come during spells of calm, intensely cold weather, from whence do they derive their electric impulse? Just let us suppose it is the result of the rapid rate of the lowering of the thermometer. That is, it is the accompaniment of the rapid rate of molecular re-adjustments of the air and its contained vapours, that is called freezing. The mere lowering of the thermometer at a rapid rate "builds up" a charge of static electricity, whether positive or negative, by reason of this molecular re-adjustment. When this charge reaches a certain voltage it necessarily "breaks down" to the level of the earth's electrical state, the breakdown taking place in the shape of an electrical shower, — namely the Northern Lights, — just as moisture-laden atmosphere causes a shower of rain to fall; and, similarly, as the air becomes clear again by showering down its excess of moisture in the form of rain, so does this electrical precipitation imply a return of the molecules of the air to their normal state.

∴ it is a reversal of the freezing process.

∴ it is a thaw, or chinook.

Quod est demonstrandum.

And that is actually what seems to happen. There can occur a fortnight, even, of repeated alternations between extremely cold days

and noticeably warm ones, and interlarded with the above defined electrical precipitation, the Aurora. It is as if the occurrence of the Aurora constituted nature's automatic check to an indefinite lowering of the temperature of the atmosphere.

At this point the question inevitably suggests itself: "Are the daily and seasonal changes in temperature related to the earth's private stock of electromagnetism?" To this question, doubtless, Science has the answer on the very tip of her tongue, or has already given the answer.

So much then for my theory of the winter Aurora,—a matter for further argument, no doubt. To the esthetic appeal of the Northern Lights at this time of the year there can be no denial, when the intense cold has crystallized the snowy nights into a strange stillness that seems to hold the very stars themselves in its spell. Then it is that the Aurora may wield its enchantment of colouring and graceful motion to shatter all this crystal immobility into dust of jewels that drifts in clouds before a soundless wind across the skyey spaces. I recall that upon one such winter night there appeared at the very zenith of the sky a golden bar of light, and knotted round it, soft folds of deepest red, like a scarf of fine tulle with lengths of free ends which lifted and gently wafted about as in a whiff of breeze,—a beautiful emblem of the wonder and mystery of all things.

After writing thus far I became curious to know what the dictionary (my entire reference library on the subject) might have to state. The only colour mentioned there, other than white, is an "orange red". But may I submit that "orange" is a sadly inadequate word to describe this ethereal, corpuscular red which I have seen in the winter Aurora. This peculiar luminosity is of a colour too deep in tone, and still having an incandescent quality, to be compared with even the loveliest of sunset hues. It has the vividness of the persecaria blossom and the depth of the red, red rose.

True I have seen at other times, far to the north, a vast orange-red flood that swirled out in ever-widening circles from the pole, mottled with gold, and whose light was like that of a forest fire—but too satanic in suggestion, it seemed to me to be quite beautiful.

Also, there is the pink colour which the lights sometimes assume

when they appear so soon after sunset that any depth of colour they might have later in the night is washed out by the lingering daylight to a mauvish pink, not unlike the sunset hues, but distinguishable usually from the sunset's afterglow by their trembling motion. After dark this shade becomes a bright violet.

Let me try to sort over my recollections of different appearances of the Northern Lights which, although they add their splendour only to the polar nights, have oddly enough been given the name of a classic hand-maiden of the sunny climes, "Aurora, the rosy-fingered daughter of the morn." Beginning with the least spectacular appearance, when it is no more than a bright fog lighting up the star-filled sky and at first hardly to be distinguished from star light, this smothering mist presently makes the stars grow pale as it intensifies and takes form, a great mass of dilute white light, that has a kind of lolling motion like a slackening balloon. Out from this almost immediately there unfurls itself a wide white banner that flings itself across the sky with a boiling and unrolling motion (like a toy swatter when inflated). Or this banner may make its appearance only by imperceptible degrees of increasing brightness. Sometimes there come to be several banners stretching across the sky at the same time.

Have they any definite direction? Possibly they lie most often from east to west, and when, as may happen, a band takes on the appearance of rigidity (like the rim of a vast wheel) and is set in motion, the axis of that wheel would seem to be through the north star or thereabouts, and the motion west to east. But not to let my figure of speech obscure the facts, let me explain that this motion, which is often very spectacular, is one of revolution in appearance only. Actually the motion is of the "stationary wave" variety, the pulses that travel along the path of light resulting only in alternately crowding and separating its rays. These banners may fade at any moment, apparently after a brief glimmering, or they may go through a series of fascinating motions flinging back and forth over the sky in wide arcs; or, as described above, they may quiver along their lengths with a rippling motion. Several of the outflung banners may now coalesce, or, again, they may widen out to cover the whole sky, giving a light equal to the brightest moonlight.

After this initial performance has faded from the sky, there perhaps occurs a repetition, usually with only a few minutes' interlude, and showing some differences. This time there is no banner outflung, but from the first mistlike mass of brightness there suddenly develop long brittle needles of light that dart far out into the heavenly spaces like slender rapiers that flash and feint. Then these needles disappear, momentarily dissolved back into the mass, again to dart out more vivid, more compactly spaced, to finally coalesce into an exceedingly bright beam of white light, so bright indeed that I have seen it reflected in the water in a long path exactly as moonlight is reflected.

Still another variation may occur. Instead of the effect culminating in wavering or taeniform banners or a straight beam of white light, the picture I now recall is of light rays diverging from several focal points near the horizon. Not so engaging is this effect unless, as happened last autumn, these several foci are in coloured lights and accompanying a coloured Aurora overhead. Truly the most spectacular wonder of the northern sky is this last-mentioned manifestation. Such in character were the Northern Lights on a night of October last year,—a barrage of bright green searchlights along the western horizon while over the whole northern half of the sky sheets of green light played like summer lightning amid amethyst and emerald and silver. On that occasion, so intense was the force, of whatever nature it may be that causes the lights to appear in the sky, that at the moment of brightest, most concentrated, white light, it was suddenly transformed, by some miracle of the ether, into the most vivid colours of the spectrum. Fluted white ribbons of vibrating light rays one minute became in the next instant processions of sharp tongues of flame, violet in colour along their joined bases, a flashing green at their tips, and the lot of them chasing one another like madcaps athwart the milky way. Rows of amethyst-tinted candles burning with bright emerald flames set in close rows on a rapidly whirling candelabrum,—that is the picture that painted itself against the velvet blue of the night sky, and remained there for some minutes, out-rivalling the silver radiance of the moon which was at the full. To be sure, the candelabrum itself was invisible, but

with a little imagination one could sense its crystal shaft pivoting at the pole and its crystal arms tracing the swinging meridians of the night. Again I must check my simile with the facts. Though the rows of flames appeared to revolve, the motion was that of a stationary wave as described in an earlier paragraph. The colours that appear in the Aurora are the individual colours of the spectrum of white light and combinations of these, violet, blue, green, yellow, orange, red, etc.; and sometimes I have dallied with the idea that these lights are no more than a solar spectrum spread out to our view, a kind of rainbow of the night sky. However, the rhythmic agitation to which the light is so often subject and the lack of any apparent relation to the position of the sun makes me doubt that the Aurora is in any way incidental to the sun's light. It could more readily be believed that the spectrum of the sun's light is itself the incidental phenomenon to some more fundamental mystery.

A more commonplace phenomenon than the sun's spectrum suggests itself for comparison with the Aurora, and that is the discharge of the atmospheric electricity seen as lightning. It seems to me that whatever explanation serves to account for the charges of static electricity, which give rise to lightning between two clouds or between a cloud and the earth, should also supply the explanation of the source of the electrical charges which give rise to the Aurora.

The fact that so many of the finest displays that I have witnessed followed upon a day or days of high gales of wind leads me to account these gales as the source (in part) of the static charges, *i.e.*, built up by friction which in the dry air of the north result in the beautiful discharges we call by the poetic name of "Aurora". It is probably of significance in this connection that as one goes north from equatorial regions electrical storms lose more and more of their virulence, even as the Aurora becomes more and more intense. The decrease in the moisture of the atmosphere might account for this; that is to say, lightning is a phenomenon of the clouds, the Aurora is the twin phenomenon of dry air. In the laboratory it is possible to obtain most of the colours of the Aurora individually by the discharge of high voltage electricity through glass tubes containing different gases, such as nitrogen, helium,

hydrogen, carbon dioxide, etc. The peculiar white light of the Aurora, also the violet and the deep aurora red, can be duplicated in the laboratory in this manner.

As to one's outdoor observations, it would not do to confine them to the nights when the northern lights are exceptional in brilliancy. Even as I write, the static that is spoiling the radio's performance this evening bespeaks the presence of the Northern Lights, although on going to investigate, their appearance is not at all impressive to the eye. There is only a white glow above the horizon in the neighbourhood of the magnetic north, sharply outlined above a circular region empty of light. Nevertheless, that half-circle smudge of darkness is probably worth much by way of "data". If I recollect correctly, this dark space before the cathode is also to be seen in the discharges through the glass tubes in the laboratory (above referred to). It may be worth as much, therefore, as an aid to solving the auroral equation, as some such unique appearance as we had in the summer of 1929. Near the end of July one midnight the sky was filled with bright white lights in the form of many downward hanging fleeces as of spun glass, whose trailing ends scarce cleared the tree-tops—an almost cyclonic manifestation of electrical forces.

One final aerial observation I should like to recount, because it serves to bind together into a consistent whole my two theories, namely, of static due to changes in temperature, and of static due to high winds. It is this. When high winds accompanying a drop in temperature, they seem to check rather than to intensify the Aurora,—that is, the sum of the two electrical charges is less than either charge alone, which is as it should be. For, whether the static of the high winds be positive or negative with regard to the earth, it is of a nature that accompanies a rise in temperature rather than a drop, since friction generates heat, and therefore it is opposite in sign to the static that accompanies freezing. Hence the one tends to cancel the other.

Likewise, having in mind the direction of the earth's rotation I should expect to find a difference in the resulting intensity of the Aurora when the winds blow from the east and when they blow from the west. But of this I have never taken any note. Too often

an east wind is a wet wind, and almost surely so if it is a gale.

Now to return to earth. A good many years ago, the phenomenon of the spectrum colours being produced by natural agencies other than the sun, was brought to my attention in a very striking way. I was passing the early part of winter on the shore of a small lake in the north that overlay a body of radioactive ore. The lake had frozen over with thick ice all in one night. Then there followed milder weather and resulting foggy atmosphere. The surface of the ice became covered with hoar frost—hoar frost such as only the north can produce—composed of clusters of little ice fans, each fan being quite an inch across and having minutely sharp points of ice protruding along its rim. These small fans standing upright in thick clusters formed a dense bristle of points over the upper side of the ice. One mid-afternoon, looking from the door of the cabin, I beheld a miracle of colour over the lake. There lay a monster spectrum spread out to a depth of a few feet upon the hoar-frosted surface of the ice,—electric-blue, green, on through to deep aurora red, extending in all about fifteen hundred feet, its lovely ethereal hues a benediction of beauty against the foil of towering grey cliffs on either hand, with their pine-darkened seams and crests. Looking at it almost horizontally, and at that distance, about the length of a mining claim, and in the daylight, the blue-green end of the coloured acreage had the effect of a highly-coloured opal,—sometimes it was the green I could distinguish, then it was the blue, or an indistinguishable blending of the two. But the red end of the spectrum, which was very much greater in extent than the rest, washed up to the very shore on which I stood, so that I could judge of its character without any manner of doubt as to its appearance. It was the deepest colouring possible, short of a spilled vat of carmine paint. Although it was not the hour of sunset, I looked to the west expectantly to see from whence such an unusual reflection could be coming. There was not a hint of these colours in the west, or anywhere in the sky. How to account for it! It was the happening of a lifetime!

Here again it seems to me, the explanation is the discharge of static electricity. For it is known that radioactive bodies carry a charge of electricity. The peculiar circumstances of the charged

ore-body that underlay this part of the lake being topped by a layer of ice whose surface was covered by a myriad of fine points, from which the charge could escape into the atmosphere above it would account for the astounding colour effect.

How so heavy a charge could have accumulated on that one occasion (if there was such a charge) is a matter for speculation. Possibly an air space had formed just there under the ice for a few hours, and, with the sheet of ice above it and the water over the charged ore-body below, constituted a first class condenser. Even without the air space, the difference between the substance of the ice which is pure water, and the impure water beneath it, might have served the same purpose. But whatever the mechanism nature used to bring it about, the beauty and wonder of the scene will ever be one of my most cherished memories.

Herb Lake, Manitoba,
(Lat. 54°.6 N., Long. 99°.7 W.)

THE EARTH*

1. Its Origin

By W. E. Harper

MY contribution to this evening's programme is not supposed to be of any great length or importance. I was honoured by the Executive with the task of choosing a subject for a symposium and of securing from among our amateur members those who would undertake to discuss the various phases of the subject that seemed desirable.

The subject decided upon was "The Earth." We astronomers wander off among the stars so much and know so little about our home base that you must grant the wisdom of my choice. I expect to learn much to-night, even if our speakers cannot adduce the necessary proof that the earth is flat as desired in the intimation of our President at the last meeting.

The origin of the earth is wrapt up in the larger question of the origin of the solar system. Of the genesis of the solar system possibly no theory has had such a wide appeal as that postulated by Laplace in 1796. He began with a vast nebulous mass of matter, of amount equal to what we find in the system to-day, but diffused cloud-like through space in a great, roughly spherical, formation extending beyond the orbit of the outermost planet.

With the radiation away of its heat and consequent contraction its speed of rotation, at first very slow, increased more and more until the centrifugal force more than overbalanced gravity and rings of matter were shed from its equatorial regions. These rings condensed around some particular region in them where the density was greatest and thus were born the planets.

Tennyson puts it in a nutshell:

> This world was once a fluid haze of light
> Till toward the centre set the starry tides
> And eddied into worlds, which wheeling
> Cast the planets.

*A symposium held by the Victoria Centre, R.A.S.C., March 18, 1932.

Many objections can now be levelled at the theory, and in its original form it is untenable.

The best accepted theories to-day are those designated as "tidal" in which through the close approach of another star great masses were torn out of our parent body, the sun, when it was less compact than it is to-day.

Let us examine the likelihood of such a happening. We know that the stars are bodies comparable to our sun—a million miles in diameter, moving hither and thither through space at an average velocity of 25 miles per second. They enjoy comparative isolation, for a cube whose side is 200,000 times the distance from the earth to sun would contain only one star. They are no more crowded in space than would twenty tennis balls be if roaming through the whole interior of the earth, considered as a hollow shell. And yet the chances are that some one of the ten billion stars will hit another every ten billion years. The chances are greatly increased if instead of actually colliding they merely approach within hailing distance. In some such rare encounter in the age past our earth is thought to have been pulled out of the sun.

Let us visualize the scene. Just as the moon raises tides in our oceans, so this massive intruder as it approached, raised tides in the sun's atmosphere. They became so great that, at a point right under the star, the atmosphere was drawn up to form a huge mountain many thousands of miles high. Eventually the gravitational pull of the other star overbalanced that of the sun and matter shot off towards the intruder. The amount of matter wrenched loose was greatest when the star reached its point of nearest approach; as the star receded on its way, the stream of issuing matter became less and less. Thus the filament of matter torn away may be likened to a cigar, fat at the middle, thin at either end.

The fiery spray cooled, condensed into huge drops which attracted to themselves smaller particles. Thus were the planets born, the massive ones at the middle where material was most plentiful. Through millions of years a roughly spherical form has been attained by the earth, the gases have condensed, and an atmosphere clothes the planet. Others will now take up the story.

2. Its Form and Size

By K. M. Chadwick

TO primitive man the earth was a flat disc, with its surface diversified by mountains, rivers and seas. In 500 B.C., Thales, a Greek, said the earth was a circular disc floating on the primal substance, water, as a piece of wood floats on the ocean. To Anaxamader, another Greek, also about 500 B.C., the earth was flat and placed in the centre of the world, and the sun was a hole in the solid sky through which was visible the fire which filled the rim of the Universe. To Anaximenes the earth, itself a condensation of dense air, was flat and the stars were nails driven into a solid vault.

The spherical form was asserted by Pythagorus (569-470 B.C.), who used arguments in favour of the round earth similar to those used to-day, such as (1) A ship gradually disappearing, hull first, masts later, as it recedes beyond the horizon. (2) The circular shadow cast on the moon during a lunar eclipse. (3) The alteration in the appearance of the stars in the heavens as one goes from place to place. With regard to the last point we may notice that if the earth were flat any star above it would be visible from every point on earth, and and we know that this is not true as many stars that are visible in Canada are not visible in South Africa or Australia, and conversely. On the other hand an observer on a spherical earth would see every star that is above the tangent plane to the sphere at the point where he is. The direction of this plane varies with his position. The spherical form did not become generally accepted till explorers had actually sailed around the earth.

It was discovered in 250 B.C. by Eratosthenes that as a traveller proceeded north from the equator he increased the angle of altitude of the pole star. This angle of altitude or mean angular elevation above the horizon of the pole star is equal to the latitude of the place for observers in the northern hemisphere, and, given the length of a degree of latitude, the size of the earth can be calculated. Actually the length of a degree of latitude is found to vary slightly in different latitudes because the earth is not exactly a sphere. A

better approximation to its shape is a sphere flattened at the poles and the degree of latitude is therefore longer in high than in low latitudes. Thus observation of the length of a degree in both high and low latitudes determines both the size of the earth and its polar flattening. The best determination is said to be that of J. F. Hayford from observations made in the United States and published in 1910. According to him a degree of latitude at the equator is 68.71 miles, at 45° latitude, 69.06 miles, and at the pole, 69.41 miles. From these results it can be determined that the polar diameter of the earth is 7900 miles and the equatorial 7927 miles.

The form of the earth as seen from a great distance would appear as smooth as a great billiard ball. The highest mountain and the greatest ocean depths, both of the order of five or six miles, are very small in comparison to the diameter of the earth of about 7,900 miles, and if we got so far away that the earth appeared as a twelve-inch globe at the other end of the room the mountains and valleys might be reproduced in the change in the coat of varnish on such a globe.

Astronomers have been able to determine the mass of the earth by comparing its attraction to a large ball of lead or ball of quartz of known weight. Their answer is six thousand million, million, million tons, or in other words a six with twenty-one noughts.

In short we may say that the earth is a huge sphere of 7,900 miles diameter slightly flattened at the poles and with a comparatively smooth surface.

3. Its Surface Features

By Charles Hartley

ISOSTASY is the term recently applied to that process by which the dry land and mountains are raised above sea-level, renewed and maintained there in spite of the wear and tear set up by ice and water, wind and rain, heat and cold. The earth is composed of water, density one; dry land, chiefly acid rocks, average 2.67; basalt, average 3, occurring in surface discharges, sea-bottoms and below oceans and lands; lastly a semi-metallic core.

The continents float like icebergs with seven-eighths submerged

on a viscous substratum of basalt, once liquid, now below the melting point. The higher the dry land, the deeper is the submerged "compensation."

The internal heat of the earth is maintained by the disintegration of radio-active substances and is generated more rapidly than it escapes outwards. After millions of years the substratum reaches its melting point, 1160° to 1170°. As the basalt liquefies, the "compensations" are partly melted and the continents sink deeper; seas spread over land previously dry, covering perhaps one half of our present surface; deposits of detritus with fossils accumulate on the new sea-bottoms, lowering their beds still further. The liquefied basalt expands 12 per cent in volume, straining and cracking the shell of the earth and, being affected by tidal forces, is discharged in enormous volumes over ocean-beds and at weak spots in the crust, especially at the junction of land and water. Hence also arise rift-valleys with volcanic activities far beyond modern experience.

By the discharges the internal tension is relieved, the basalt cools, hardens and contracts. The earth's circumference is shortened; the ocean bottoms become corrugated and press literally on the shores of continents, overthrusting and contorting old rocks and new sediments. The continents rise, carrying up old and new alike; the crust buckles and is forced into mountain ridges and plateaus. The forces of disintegration renew their work and recommence the process of demolition. The whole cycle from beginning to end is called a *revolution* and is believed to occupy a period of 25 to 30 million years. The last mountain building epoch occurred a few million years ago and the high lands already show the marks of nature's ravages. The substratum is now approximately solid except along lines of weakness marked by volcanic activity.

4. Chemical Composition of the Earth's Crust

By T. J. Greenway

THE conception of the structure of the earth which is now most favoured by geophysicists is that it consists of an iron-nickel core surrounded by an envelope of rock-forming material having a chemical composition which varies outwardly from something

like our more basic igneous rocks of the basalt type to that of our more acidic igneous rocks of the granitic type, and that this envelope of rock-forming material has a covering consisting chiefly of solidified igneous rock, which we call the "earth's crust." In order to satisfy gravimetrical calculations, it must be assumed that the iron-nickel core has a diameter of between 5,000 and 6,000 miles, and that its envelope of rock-forming material has a thickness of between 1,000 and 2,000 miles, while geological, seismic and other calculations indicate that the external "crust" has a thickness of no more than about 50 miles.

Various views are held concerning the physical character of the vast mass of material which is covered by the earth's crust, but as any discussion of them is outside the scope of this paper, all that need be here said in this connection is that geological investigations have indicated that the rock-forming material immediately within the crust is existing in a more or less molten condition at temperatures of between 2,000° and 3,000° C., and under pressures which are sufficient to force it against gravitation influences to the earth's surface through 30 or 40 mile volcanic vents.

Assuming that the earth's crust has a thickness of about 40 miles, it may be said that while the depths of the deepest mines and bores of the world are only about 1 mile and 2 miles, respectively, contractions and shrinkages and other movements of the earth's crust have not only brought about the formation of high mountain ranges and deep ocean valleys and thus made available for investigation an earth crust thickness of more than 12 miles, but have also so displaced and contorted average rock formations as to expose a further 5 to 10 mile thickness. It has thus happened that geologists and geophysicists have found it possible to study directly the outer 20-mile thickness, and inferentially study the inner 20-mile thickness of the earth's crust, and to publish fairly comprehensive and reliable information as to the physical character and chemical composition of the whole. This information may be summarized as follows:

(1) That the earth's crust has a thickness of something like 40 miles.

(2) That the inner 20 mile thickness consists of igneous rock

forming material existing at temperatures which vary outwardly from about 2,000° C., to something approaching atmospheric temperatures, and having a structure varying from that of a semi-molten mass to that of the crystalline igneous rocks exposed on the earth's surface.

(3) That the outer 20-mile thickness consists chiefly of irregularly disturbed stratified and igneous rock formations existing at something like atmospheric temperatures, and having structures which vary from those of highly crystalline rock masses to those of stratified indurated clays and loose sands.

(4) That the surfaces of the rock constituents of the outer 20-mile thickness of the crust are so covered by oceans and ocean extension that only 28 per cent of them are above sea level, and that if the uncovered surfaces were flattened out and brought to a common level the whole would be submerged to a depth of nearly 2 miles.

In view of the circumstances that the oceans and ocean extensions cover 72 per cent of the earth's surface, they are sometimes called the hydrosphere, and the earth is regarded as having three concentric coverings, *viz.*, the lithosphere, the hydrosphere and the atmosphere.

Inasmuch as the greater portion of the earth's crust is made up of igneous rocks, and nearly the whole of the remainder is made up of stratified rocks which are either directly or indirectly derived from the existing igneous rocks, it follows that analysis of average samples of igneous rocks will show the chemical composition of the whole. The analysis of igneous rocks No. 1, is here presented as showing the average composition of the earth's crust.

ANALYSIS No. 1.

Oxygen	47.09	Sodium	2.53
Silicon	28.23	Potassium	2.44
Aluminium	7.99	Titanium	.43
Iron	4.46	Other elements	
Magnesium	2.46	under 2 per cent	.94
Calcium	3.43		
			100.00

An outstanding feature of this analysis is the predominating proportions of oxygen and silicon shown. It should, however, be realized in this connection that neither these nor the other elements cited exist in the rocks as elements, but are present in combination with each other as oxides, silicates, etc. Therefore perhaps the re-statement of the figures of Analysis No. 1, shown in Analysis No. 2, presents a clearer view of the composition of the earth's crust.

ANALYSIS No. 2.

Silica	59.87	Sodium oxide	3.39
Alumina	15.02	Potassium oxide	2.93
Ferric oxide	2.58	Titanium oxide	.72
Ferrous oxide	3.40	Other oxides	3.24
Magnesium oxide	4.06		
Calcium oxide	4.79		100.00

Speaking more specifically of the igneous rocks which make up so large a portion of the earth's crust, it may be said that all of them belong to one of two great groups, *viz.*, (a) the granitic group, which includes the lighter and more infusible rocks, containing from 55 per cent to 80 per cent of silica, and having a specific gravity of about 2.7; and (b) the basalt group which includes the heavier and more fusible rocks containing from 30 per cent to 55 per cent of silica, and having a specific gravity of about 3.3.

For the purposes of this paper it may perhaps be sufficient to say that the granitic group includes rocks such as the various granites, porphyries and diorites; and the basalt group includes such rocks as the various basalts, gabbros and peridotites; and that all igneous rocks will melt at temperatures well below 2,000° C., and that all will become disintegrated more or less readily under atmospheric influences.

The stratified rocks, although they have been derived from the igneous rocks and have something like the same average chemical composition, differ from them very much in the matters of physical structure and individual chemical composition. Most of them may be regarded as being members of two classes, *viz.*, (a) the siliceous class, and (b) the calcareous class. The rocks of the siliceous class are composed of sands, muds and other such mineral matter which,

after having been broken away from pre-existing rocks by natural disintegrating influences, have been so water-wind or glacier-borne as to bring about the production of stratified accumulations, and these accumulations have subsequently become so affected by gravitational pressure, hydration and other indurating influences, and have been so located by earth movements, that they have become the stratified mountain and other stratified rock masses with which we are familiar. The rocks of the calcareous class have been produced chiefly from shell and other calcareous remains of mollusca, corals, foraminifera and other marine organisms which have become so deposited on the bottom of oceans and ocean extensions that they have formed stratified accumulations sometimes many thousands of feet in thickness and these have become gradually so affected by pressure, hydration and other such influences, and so transported by earth movement that they have formed the limestone formations from which the world's lime and other calcareous requirements are being obtained.

While the average chemical composition of the stratified rocks closely approaches that of the earth's crust, their individual chemical compositions vary all the way from the nearly pure silica of some of the quartzites and sandstones to the nearly pure carbonates of magnesia and lime of some of the dolomites, and the nearly pure carbonate of lime of some of the limestones. The soil formations of the various parts of the world may be regarded as belonging to the siliceous group of the stratified rocks. The various soils differ very much, and most of them are derived from, and have chemical compositions approaching those of their respectively underlying and nearby rock masses, for instance: the soils that cover granitic rocks are made up chiefly of sands and clays which are essentially disintegration products of those rocks; and the soils which cover basaltic rocks are made up chiefly of sands and clays which are disintegration products of basalt rocks. It may be here mentioned that basalt soils are usually far more fertile than granite soils; and that as they differ from the granite soils chiefly in containing larger proportions of iron oxides, it seems probable that their greater fertility is in a great measure due to their larger iron oxide contents.

As a conclusion of this discussion of the chemical composition of the earth's crust, it may be said that inasmuch as that geological and geophysical investigations have not actually demonstrated the physical character and chemical composition of the outer 20-mile thickness of the earth's crust, but also inferentially indicated the character and composition of the inner 20-mile thickness, it may be fairly claimed that the general character of the earth's crust, taken as a whole, is a matter which is very far from being a highly controversial one.

5. Composition of the Atmosphere

By W. Burton

OUR atmosphere is a mixture of gases and vapours that differ radically from each other in every particular; nor are even the relative percentages of the several distinct constituents at all constant. According to Hann, the chief independent gases that are blended into a dry atmosphere at the surface of the earth are as follows; nitrogen, oxygen, argon, carbon dioxide, neon, and helium; in addition to these, krypton and xenon also occur as permanent constituents of the atmosphere. There are also many substances, such as radio-active emanations, the oxides of nitrogen, ozone, and above all, water vapour, that are found in varying amounts. Of these only water vapour forms an appreciable percentage of the total atmosphere, a percentage that depends chiefly upon temperature in the sense that, for any given pressure, the higher the temperature the greater the percentage of water vapour. Our atmosphere consists of two distinct layers completely surrounding the earth. The first layer, the one in which we live, is the region of convection or the troposphere, the second is known as the isothermal layer or the stratosphere while the division between the two is known as the tropopause.

It is now possible to go up and observe directly the conditions in the atmosphere up to about 12 km., and some valuable data have been obtained by means of instruments carried on aeroplanes undertaking altitude tests. Sounding balloons also are sent up with self-recording instruments. In Canada the Dines meteorograph is used, the pressure is recorded by means of an aneroid box, which is connected to a fine needle point which makes a trace on a silvered

glass. Horizontal motion of the needle corresponds to change in pressure; at the same time change of temperature affects a bi-metallic strip and causes a vertical displacement of needle. When these instruments come to earth and are returned to the meteorological office they are placed under the microscope, and the readings noted.

Pilot balloons are sent up daily from the Meteorological Observatory to give us the direction and velocity of the wind, and if cloudy to get the height of the ceiling. This information is for aeroplane pilots. The balloon is weighed and the lifting capacity is determined by the weight of the rubber balloon. It is then filled with hydrogen and when the balance weight is lifted the correct amount of hydrogen is in the balloon, it is then made secure so that the gas cannot escape. The balloon is then taken on the roof of the observatory and released and its course is watched through a theodolite, and at intervals of one minute, readings of the azimuth and angular elevation scales are read. When the ballon is lost the readings obtained are entered on a plotting board to derive the direction and velocity of the wind at the different altitudes. These balloons when released rise at the rate of five hundred and eighty feet per minute. The chart obtained shows the direction and velocity of the wind at different altitudes up to 5000 metres.

6. The Motions of the Earth

By W. F. Holdridge

THE first and most common motion of the earth is the daily rotation upon its axis once a day. The motion is nearly uniform, being the sidereal day of 23 h., 56 m. The speed with which the earth is rotating upon its axis is one thousand miles per hour at the equator and a consequent zero at the poles. The rotation of the earth in an easterly direction at such a rate is the partial cause of the deviation of air currents to the right in the northern hemisphere and to the left in the southern hemisphere.

The most important movement of the earth is its revolution around the sun with its axis inclined at an angle of 23½ degrees to the perpendicular to the plane of its orbit. The earth's speed around the sun is 18.5 miles per sec., and it approaches closest to the sun in its orbit at perihelion (about January 1). The sun is not fixed but shares in the general motion of the whole solar system relative

to the stars at a velocity of about 12½ miles per second towards a point in the constellation of Lyra. The sun is close to the centre of mass of the solar system but moves with regard to it on account of the attractive forces of the other planets on the sun.

The revolution about the sun and rotation were both established by Copernicus in 1543. Later the explanation of the revolutions of the planets was the greatest triumph of Newton's Laws of Motion.

There is also a movement of the axis with respect to other heavenly bodies known as Precession. The axis upon which the diurnal rotation is performed is not absolutely fixed. Owing to attractions of the sun and moon upon the equatorial bulge of the earth a disturbance is set up analogous to that of a top spinning upon its axis, and tracing a path of 47 degrees similar to that of a cone. We thus have a slow precession along the ecliptic amounting to only 50 sec., of arc per year. From this we find that the star which bears the name of Pole star is not always the same. At present it is the star at the extremity of the tail of the Little Bear. The true celestial pole will approach Polaris until 2105 A.D., will then recede, and other bright stars will take the place of the present pole star. The axis of the earth thus traces out a complete circle in the heavens in 25,800 years.

Nutation.—The force tending to alter the tilt of the axis is not constant. When the sun or moon is crossing the equator, for instance, there is no effect. The path of the pole, therefore, in its journey through the stars is not of uniform velocity and is not quite a circle.

The axis of rotation is not exactly fixed with respect to the earth, *i.e.*, the poles of the earth are not fixed points on the earth, but are continually changing. This fact was discovered by accurate determinations of latitude and for that reason is known as variation of latitude. The pole wanders from its mean position not more than 30 feet corresponding to a change of latitude of 0.3 second of arc. It consists of two small movements of periods approximately 12 and 14 months, which are probably the result of meteorological causes.

Conclusions:—The earth has five principal motions.

(1) Its diurnal rotation on its axis.

(2) Its yearly revolution about the sun in a nearly circular orbit and at a mean distance of approximately 93 million miles.

(3) A motion known as the Precession of the Equinoxes in which the earth's axis is slowly tracing out a path among the stars, making one complete revolution in 25,800 years. An irregularity in this motion is known as Nutation.

(4) The wandering of the pole from its mean position on the earth's surface.

(5) The motion through space in company with the sun and other members of the solar system.

REVIEW OF PUBLICATIONS

Annuaire de l'Observatoire Royal de Belgique. 1933. Edited by P. Stroobant, Director.

The centenary volume of this useful handbook has been received. The Annual of the Royal Observatory of Belgium has been published without interruption since 1834, and, according to the preface, "has for its purpose the providing of information which is indispensable to the public services, and also of supplying brief instructions to those persons, always increasing in numbers, who desire to observe the phenomena of astronomy and to acquaint themselves with progress in the science of the heavens".

The Annual contains, in addition to the ephemeris of the sun and moon for both Belgium and her Congo colony, a large and varied amount of valuable information, including data concerning the many calendars in use throughout the world; aspects of the planets, with charts illustrating their paths among the stars; tables of periodic comets, with historical notes on those whose return in 1933 is expected; eclipses of the year, and occultations of stars by the moon; a catalogue of the principal stars; also tide tables for the coasts of Belgium.

Dr. Stroobant and the staff of the Royal Observatory of Belgium are to be congratulated upon the occasion of the publication of this one hundredth volume of the Annual.

Toronto, July, 1932. F.L.T.

NEWS AND COMMENTS

NOTES FROM THE DOMINION ASTROPHYSICAL OBSERVATORY

The observing statistics will first be given for the past five months, in continuation of those in the April issue:

	1932		13-year average	
Month	Nights	Hours	Nights	Hours
March	9	46	16	104
April	16	79	17	99
May	23	106	21	108
June	20	95	19	88
July	13	70	26	136

The month of March was the poorest since observation began and with the exception of 1918 the past month of July was also a record for poor observing. Local meteorological statistics show it to be the wettest July for sixty years. There is always a silver lining to every cloud, though, and if there have not been clear skies at least such has not been due to smoke from forest fires which is too often the case.

As mentioned in a previous note, the Government has widened the road leading up to the Observatory from the main road, the distance being about one and one-third miles. Unfortunately in the process many sharp pieces of rock were scattered about and it almost seemed, from the number of new tires the members of the staff had to purchase, that the road makers were in collusion with the tire dealers. Sufficient money was supposed to be reserved from the appropriation to provide for surfacing, but up to the present such has not been done.

The Director, Dr. J. S. Plaskett, and Assistant Director, W. E. Harper, attended the annual meeting of the Royal Society of Canada held in Ottawa May 26-30, and renewed acquaintances with eastern friends. Dr. Plaskett went a few days earlier in order

to be present at the convocation of McGill University, where he was honoured with the degree of LL.D. for his researches in science.

The Astronomical Society of the Pacific held its spring meeting in conjunction with the Pacific Division of the American Association for the Advancement of Science at Pullman, Washington, on June 15-18. The Director was one of five invited to participate in a symposium on the opening afternoon reviewing the year's achievements in the various sciences. Unfortunately Dr. Plaskett found himself unable to attend and your scribe, who was chairman of the Program Committee, was also absent. A total of 20 papers were presented, seven being from this institution. Owing to preparations for the coming eclipse many astronomers could not arrange to be present and the attendance in this division was small.

Following the meeting Victoria was favoured with the visit of several of those at the meeting. Miss Phyllis Hayford, daughter of the late head of the Coast and Geodetic Survey, with her mother, drove up and gave a short impromptu talk on her work at the Lick Observatory on the galactic rotation effect in open clusters. This was the subject of her thesis for her Ph.D. degree, just awarded. Dr. F. J. Neubauer, also of the Lick Observatory, and Mrs. Neubauer, spent a day in Victoria following the meeting. Dr. T. S. Jacobson of the Department of Astronomy of the University of Washington, Seattle, paid a flying visit on the same day as the others, while a few days previous to the meetings we had a visit from Mr. W. H. Christie, now of Mount Wilson Observatory, but formerly connected with the observatories at Victoria and Ottawa.

Professors J. S. Foster and Miss A. Vibert Douglas were here for a month securing spectra in connection with the so-called Stark effect. With a little adjustment of nights on the part of the regular observers they were able to secure the desired observations and departed July 19th for the east to make preparations for the eclipse.

Dr. R. J. Lang of the University of Alberta, Edmonton, accompanied by Mrs. Lang, spent a day at the Observatory in the middle of July.

Miss Winter-Hansen of Copenhagen, Denmark, who is touring American observatories prior to taking in the eclipse, gave us a delightful informal account of her work in the observatory at Copenhagen and of items of general interest. One carried away the impression that the Danish government is much more liberal in supporting astronomical work than is the case in some other countries.

Andrew McKellar, formerly a summer assistant here and now pursuing post-graduate studies in the University of California, called on us on his way home at the close of the spring session. He is working on the isotopes of boron under the guidance of Professors Birge and Jenkins.

Our heartiest congratulations are extended to Robert M. Petrie on his being awarded his Ph.D. degree by the University of Michigan at this year's commencement excerises. His thesis was "A Spectrographic Study of RT Aurigae". "Bert" was for several summer vacations connected with our own observatory and did splendid work while here. We are not surprised that the Detroit Observatory, where he has been taking his post-graduate work, wishes to retain him on the staff.

Rollin W. Gillespie, a graduate in chemistry of Washington University, St. Louis, Mo., spent a few days with us at the beginning of August. While specializing in chemistry he is greatly interested in anything pertaining to our astronomical work.

A party of English and foreign astronomers headed by Sir Frank Dyson, are due in a day or two (at time of writing), and expect to stay here four days. Then two days will be spent at each of the Lick and Mount Wilson observatories before returning east for the eclipse and the meeting of the International Astronomical Union. A rather strenuous bill of fare has been provided for them here during their four-day visit.

W.E.H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Japanese Astronomical Events

From Mr. Yasuaki Iba, of Gochome, Ohte, Kobe, Japan, I learn that an expedition from Japan will observe the eclipse of the sun and afterwards attend the I. A. U. It consists of Professor Hirayama and Drs. Mitsuo Oikawa, S. Notsuki, and Yoshio Fujito, all of Tokio. They will observe from Bartlett, N. H. Within the last year the Tokio Astronomical Observatory has lost three able astronomers, all astrophysical experts.

Mr. Iba in recent months has been assiduously making photographic observations of comets, and from his plates has obtained positions which have assisted in orbit determinations.

Keeping Up a Family Record

The family of Struve is famous in the history of astronomy. Friedrich Georg Wilhelm (1) had a son Otto Wilhelm (2) who had two sons Karl Hermann (3) and Gustav Wilhelm Ludwig (4). Karl Herman (3) had a son Georg (5) and Gustav Wilhelm Ludwig (4) had a son Otto (6)

(1) Friedrich Georg Wilhelm was born at Altona, Germany, in 1793, went to Russia and at twenty was appointed director of the newly organized observatory of the University of Dorpat. In 1839 he was made director of the Imperial Observatory at Pulkowa, and died in 1864. He is especially noted as a pioneer observer of double stars.

(2) Otto Wilhelm was born at Dorpat in 1819, became an assistant to his father and continued his work on double stars. At the age of 22 he made a notable investigation into the motion of the solar system, and he is also distinguished for his work on the parallax of the sun and the stars. He succeeded his father at Pulkowa in 1861. In 1879 he ordered from the Clarks a 30-inch

refractor which was mounted in 1884. It was the largest then in existence. In 1890 he retired and lived in Germany where he died in 1905.

(3) Karl Hermann became director of the observatory of the University of Berlin.

(4) Gustav Wilhelm Ludwig was born at Dorpat in 1858. He became observer at the Dorpat Observatory in 1886, and in 1894 went to Kharkov to become director there.

(5) Georg, son of Karl Hermann, is a member of the staff of the observatory of the University of Berlin which is now located at Berlin-Babelsberg.

(6) Otto, son of Gustav Wilhelm Ludwig, was born at Kharkov in 1897. He came to the United States in 1921 and became an assistant in stellar spectroscopy at the University of Chicago. In 1923 he obtained the Ph.D. degree and in 1924 joined the staff of the Yerkes Observatory. In 1931 he was made assistant director, and on August 1, 1932, on the retirement of Edwin Brant Frost, became director. Professor Frost was at the head of the observatory for the last twenty-seven years, and his many friends will wish him many more happy years at Williams Bay where he will continue to reside.

Preparations for the Eclipse

These notes are being sent forward from St. Alexis des Monts, P.Q., where the eclipse expedition of the University of Toronto is located. This is a small French-Canadian village about 25 miles north of the St. Lawrence river. It is picturesquely placed in a charming valley through which flows the small river du Loup, and on all sides rise beautifully wooded hills. The site for observations is on a hill about sixty feet high, cordially offered to us by M. Alphonse Tremblay, its owner. This issue will appear at about the time the eclipse takes place.

C. A. C.

MEETINGS OF THE SOCIETY

AT VICTORIA

April 22, 1932.—The abstract of the paper on "Seismological Observations and Slow Earth Movements" presented by Mr. F. Napier Denison, superintendent of the meteorological station at Victoria, B.C., was inadvertently omitted from the minutes.

In introducing this subject Mr. Denison stated that the Milne Type of seismograph installed at Victoria in 1898 and the one set up at the Toronto Observatory in 1897 were the pioneer ones in Canada.

Apart from the measuring of the earthquake records, Mr. Denison has been making a special study of slow earth movements as shown on these records during the past 33 years, and has presented papers on these movements at the 1901 Glasgow B.A.A.S. meeting and at the International Seismological Congress at Manchester in 1911.

In 1914 better facilities for the carrying on of this work were provided by the erection of the Gonzales Observatory by the Dominion Meteorological Service, and in 1923 the latest type of Milne-Shaw seismographs were installed here.

Owing to the ideal rock foundation here an average of 230 earthquakes per year are being recorded and many of these originate in distant parts of the world.

By means of lantern slides the annual earthquake frequency curve was shown for the past 33 years in which cyclic variations could be detected.

Marked secular changes were also shown in the horizontal pendulum movements during the above period, and from the mean monthly values for this long period of observations it is seen that the E-W pendulum reaches its maximum easterly movement in June and its westward extreme in November. As these seasonal changes are supposed to be caused by temperature conditions the mean monthly temperature curve was also shown, clearly demonstrating that the maximum occurs in July and the minimum in January.

A new seismograph designed by Mr. Denison for the Provincial Department of Mines was shown. This instrument, which is entirely of local construction, is designed for use in the coal mines, and it is hoped that by keeping a close inspection of the photographic records taken from it daily, as well as noting the minute changes on the graduated sight scale, it will be possible to detect the beginning of slow rock movements in the mines before they develop into dangerous conditions such as "bumps", etc.

Summer Activities

To stimulate interest and knowledge of practical astronomy, to afford an opportunity for constellation study and for experience in observational work, this Centre has instituted a series of weekly meetings to be held at the private observatory of a member.

The programme, prepared by a committee consisting of Dr. J. A. Pearce (chairman), Dr. Frank S. Hogg, Mr. Charles Hartley and the secretary, follows:—

July 12—The Celestial Sphere ..... J. Duff
July 19—The Summer Constellations ..... W. E. Harper
July 26—Systems of Co-ordinates ..... H. B. Brydon
Aug. 2—The Earth, its Shape and Size ..... J. Duff
Determination of Latitude ..... J. A. Pearce
Aug. 9—The Moon ..... C. Hartley
H. B. Brydon
Aug. 16—Time, Solar and Sidereal ..... C. S. Beals
Aug. 23—Constellation Study ..... J. A. Pearce
(Problems on the Celestial Sphere)
Aug. 30—Naked-eye Variable Stars ..... F. S. Hogg
Sept. 6—The Planet Saturn ..... H. B. Brydon
Sept. 13—Meteoric Showers, the Perseids ..... J. Duff

Limited accomodations prescribed a maximum of 20 persons but 30 were present at the first meeting.

In his talk on the Celestial Sphere Mr. Duff described and illustrated by a model the horizon and equatorial systems and briefly touched upon the ecliptic system, concluding by showing the set of slides prepared by Dr. Chant on the celestial sphere and its motions.

After the lecture the 4-inch refractor in the observatory was examined and the principles of the equatorial mounting explained. Rain unfortunately prevented observation. This telescope originally belonged to A. F. Miller of Toronto. Mr. Miller is one of the Charter Members of the Astronomical and Physical Society which developed into the Royal Astronomical Society of Canada.

H. Boyd Brydon, *Secretary.*

AT OTTAWA

January 29, 1932.—This evening the Ottawa Centre held the first of a series of four informal technical lectures at the Dominion Observatory. As the room available for these lectures is small, the attendance is to be confined mostly to members of the Centre.

The address was given by R. Meldrum Stewart, Director of the Dominion Observatory, and the subject was "The Theory of Errors". Mr. J. S. Lane presided at the meeting.

It is hoped that an account of this lecture may appear in the JOURNAL at a later date.

A discussion took place after the lecture, and the president thanked Mr. Stewart for the trouble he had taken in preparing and giving his talk.

February 19, 1932.—The fifth regular meeting of the season was held in the Victoria Memorial Museum. The President, Mr. J. S. Lane was in the chair.

Mr. Lane introduced the speaker, Dr. R. W. Boyle, Director, Division of Physics and Engineering, National Research Council. The subject of Dr. Boyle's lecture was "Up-to-date Puzzles (Theories in Physical Science)".

"The lecture first rapidly surveyed the well-known physical researches which led to the identification of the electron and proton, and continued into an outline of the theory of atomic constitution by Rutherford and Bohr. The chain of evidence which led to Planck's quantum theory of radiation with its universal quantum constant (h), and the association of quantum theory with current atomic theory of radiating atoms was briefly reviewed, and the idea of the *photon*, as specified by the well-known basic relation $e=h\nu$, explained.

Practically a new Physics begins at the opening of this century, for important phenomena lead to what is virtually a new quantum theory. The new theory introduces difficult puzzles, by no means all solved, but offers new and clarifying views on what heretofore seemed to be intricate complexities of nature. The photo-electric effect and certain x-ray phenomena show experimentally that the energy of an electron ejected from an atom is proportional to the frequency of the associated radiation, as the quantum law requires; but, more startling than this, researches in recent years show that electrons, instead of behaving always like particles may behave also like waves, our interpretation of this behaviour depending upon contingent circumstances. We have therefore the puzzle of waves of radiation behaving like little particles (photons) and little particles (electrons) behaving like waves; we have to reconcile the facts that energy may have both wave and particle aspect, and matter have particle and wave aspect as well.

The new method of wave mechanics is making advances along the road which leads to a more general and consistent hypothesis in which particle and wave ideas are reconciled. Important experiments leading to the wave hypothesis, namely those of Davisson and Germer and also of G. P. Thomson, were briefly outlined and from them basic ideas of the wave mechanics theory were explained.

The wave mechanics grasp the notion that an electron as a simple particle is only an approximation useful when the electron strikes obstacles or passes through apertures large compared with itself, but not so useful in comprehending phenomena if the obstacle and apertures become really small. This new physics obliges us to study the reactions of electrons, protons, photons on small obstacles and on one another in appropriate detail

and finer than ever before. What we see or perceive in the macroscopic world is merely an average or statistical effect, and caution is necessary in attributing to individual molecules, atoms, electrons and protons the properties and laws evolved from observations and experiments on gross matter in bulk. So we must study the progressive spreading of waves as electrons, protons, photons travel or impinge on one another. This was the main idea of the new methods of wave mechanics as founded by De Broglie and Schrödinger.

There is no absolute contradiction between the aspects of particle and wave for these entities. The new ideas of Bohr and Heisenberg show in fact that these properties are complementary rather than contradictory. If an experiment is devised to display the wave aspect, its very conditions will bar a disclosure of the particle aspect of any atomic entity, and vice-versa. The connecting link between both aspects is the *quantum*, the guiding principle which establishes the basic idea being the Principle of Uncertainty. Phase and group velocities of electron waves, and the idea of least action, were briefly explained in the lecture, from which followed a rudimentary exposition of the Uncertainty Principle and its application to the uncertainties of position, velocity, energy, momentum, etc., of the electron, from which there appears to be no escape.

A brief explanation was given of the Exclusion Principle of Pauli, with reference to its application in magnetism and in the theory of electric conduction in metals.

The polarisation in electron waves and demonstration of the existence of spin in the motion of the electron were illustrated by the important experiment of Stern and Gerlach. The Uncertainty Principle apparently makes it impossible to compute a clear separation between the magnetic effects of spin and orbital motion of the electron. Brief notice was made of recent work of Dirac.

The lecture concluded by pointing out certain questions concerning electric charge which the quantum-wave mechanics theory avoided, and indicated certain needs for decisive experiment."

Dr. Boyle illustrated his talk with some slides. At the close of his lecture, Mr. Lane thanked the lecturer on behalf of the society for his interesting talk.

March 4, 1932.—This was the second of the series of four informal technical lectures, at the Dominion Observatory. The president, Mr. Lane was in the chair.

The speaker of the evening was J. P. Henderson, M.A., of the Dominion Observatory, and his subject was "Electron Emission in Radio Tubes".

The lecturer spoke in part as follows:—"When a curve is plotted with the applied voltage on a device as abscissa, and the resultant in phase current as ordinate, its operation can be predicted. It matters not whether readings

are taken in the same circuit, such as with an arc and vacuum discharge, or in different related circuits of an audion tube when the voltage as applied on the grid, and the current as resulting in the plate circuit are read. The characteristic curve for the alloy constantin may be nearly a straight line, while that for iron drops off as temperature rises and for carbon the curve becomes steeper. Any arc, gas discharge, dynatron, tungar, etc., show reversed characteristic, *i.e.*, as the current rises the voltage across it decreases, due to additional electrons being at liberty in the ionized gas, and hence for stabilization must have a resistance in series whose value for any operating state may be deduced from the slope and position of its curve at that point. Such devices may be used to sustain oscillations in suitable attached circuits.

The presence of gas is often beneficial in increasing the apparent electron emission, as in photo-electric cells, where light falling on a surface such as rubidium, potassium, etc., liberates but a few electrons in itself but these set others free in the gas.

Non-uniform conduction or emission of electrons at certain voltages occurs in crystal detectors, cupric oxide rectifiers, mercury surface, aluminum with oxide coating, and in materials like zinc oxide, eosine, etc., when light falls on them, most of these features being utilized commercially.

Electron emission from hot filaments is facilitated by impregnating the tungsten with thorium, or coating with barium oxide. When a battery with a rheostat is used on radio tubes the electron stream can be varied and the characteristic curves made to suit our needs, but with heater tubes run on a.c. it becomes necessary to supply some other means, such as other control or screen grids, etc., through which the electrons must pass in addition on their way to the plate.

For detection or rectification a sharp inflection at one end is necessary while for amplification the curve should be straight over the required grid swing. Also if the grid is allowed to take any current, such as go positive to the filament, it forms a load on the feed circuit, destroying its sharpness of tuning as well as wasting power and possibly its saturating iron cores of transformers. By having more electrodes, the shape of the curves may be varied, such as in a "variable mu" tube, and modulation or oscillation may be introduced on a grid doing only the one duty, while some other function occurs on another.

If a tube starts to oscillate no matter at what unknown frequency, say due to dynatron or negative resistance effect, the swing of the grid may be so wide that any signal wave brought in to act on it may be negligible in comparison, and is wasted, or the signal may be sufficient to 'trigger' off spontaneous oscillation during part of the time, resulting in distortion of the amplified signal.

The grid glow tube is one whose plate current in a gas is started by a potential between two other electrodes, but once started its magnitude has

no relation to the control circuit and must be stopped by an interruption in its plate supply.

The penetration of x-rays is under much better control where electrons are supplied by an incandescent filament and there is not the waste of high voltage energy that formerly was necessary to release them from cold electrodes.

In cathode ray oscillographs the stream of electrons from the hot cathode is under control and is deflected successively by two pairs of electrodes at right angles, allowing study of these forces which are measures of the two voltages, for curves are traced on a fluorescent screen where the electrons strike."

At the close of the lecture, a very lively discussion took place, in which the lecturer very kindly answered and explained many questions. Following this, a demonstration was given of a photo-electric cell with tube amplifiers, neon gas discharge, and a tube connected with meters to plot its curves, as well as show oscillation and dynatron effects in radically changing normal operating characteristics.

On behalf of the society, the president thanked Mr. Henderson for his talk, and also for the trouble he had taken in arranging the demonstrations.

April 16, 1932.—This was the third of the series of four informal technical lectures, at the Dominion Observatory. The president, Mr. Lane was in the chair.

The speaker of the evening was A. H. Miller, M.A. (Oxon.), of the Dominion Observatory, and the title of his talk was "The Theory and Operation of the Eötvös Torsion Balance".

It is hoped that this paper will appear in the JOURNAL and it seems unnecessary to add more for the present.

At the close of the lecture there was some discussion and a torsion balance was exhibited.

MIRIAM S. BURLAND, *Secretary.*

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